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THE PARAMETERS OF INVENTORY MANAGEMENT DECISIONS

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THE PARAMETERS OF INVENTORY MANAGEMENT DECISIONS

by

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1946

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A thesis submitted to the faculty of the School of Government, Business and International Affairs of The George Washington University in partial satisfaction of the requirement for the degree of Master of Business Administration.

June 5, 1963

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PREFACE

The practicioner of the science of inventory management will soon note that I have successfully avoided any mention of several concepts vital to that science. Some of these include such fundamentals as safety limits, shortage costs, supply effectiveness, and military essentiality. Their importance is definitely recognized; however, out of a profound respect for the breadth and depth of the problems associated with each of those concepts, I have left them for the contemplation of future students. Each would be an area where research would be fruitful, I am sure. I have intentionally limited the scope of this paper, motivated by the time limitations imposed by the other requirements of the academic curriculum in which I am enrolled, to dealing with that part of inventory sometimes referred to as the "operating level of supply." This is the part over and above the safety level and is the part susceptible to replenishment through the use of economic order quantity formulae.

I am grateful for the suggestions of my contemporaries, for the patience of my family, for the information furnished by the officers and civilian employees of the Bureau of Supplies and Accounts, and for the others who have given so freely of their time. I am much indebted to the Commanding Officer of the Ships

Parts Control Center, Mechanicsburg, Pennsylvania, and especially to Lieutenant Commander C. Woodford Rixey, Jr., Supply Corps, U. S. Navy, for the sample data included in Chapter III concerning the analysis of the total annual costs of inventory management as simulated for material controlled by that command.

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CHAPTER I

INTRODUCTION

The Economics of Inventory Management

The Department of Defense requires that the replenishment of stock at secondary activities of the various distribution systems be based on "economic considerations, item characteristics, and performance objectives."[1] Replenishment of stock items based on economic considerations requires the use of formulae in which the quantities to be ordered and the reorder points are functions of the several costs incurred in the management of inventories. These formulae are in use for segments of the Navy supply system and are similar to those which are generally accepted and in use today in industry. The reorder quantities which are computed with the formulae are sometimes called "economic order quantities," "economic purchasing quantities," or even "economic buy quantities." These terms will be used interchangeably throughout this paper, especially in quoting from the authorities used for reference purposes. There also are a number of names given to the rules

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[1] Department of Defense Instruction 4140.11 of 24 June 1958.

themselves. Some of these are "mathematical decision rules," or "scientific decision rules," and in some of the cases, "E. O. Q." (economic order quantity).

The mathematical derivation of the formulae would be redundant here. If the reader is interested, there are several authorities available on the subject in which the derivation is included.[1]

It is postulated that the most economical method of managing inventories would result when the costs associated with ordering and the costs associated with holding the material in store were at a minimum. These costs are more inclusive than sometimes realized. As defined by the Stanford Research Institute:

> The costs associated with holding an item in storage include not only the physical holding costs (warehousing, etc.), but the interest cost of money financing the material, and the obsolescence risk rate. The costs of ordering represents the additional cost that would be incurred (or could be saved) by placing (or not placing) one order.[2]

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[1] The reader is referred to T. M. Whitten, Theory of Inventory Management, 2nd Ed., (Princeton: Princeton University Press, 1958); The Economic Order Quantity--Scientific Inventory Management Simplified, Superintendent of Documents, U. S. Govt. Printing Office, Wash. D. C. (45¢); E. Everet Welch, Tested Scientific Inventory Control, (Greenwich, Connecticut: Management Publishing Corporation, February, 1958); John F. Magee, "Guides to Inventory Policy I: Functions and Lot Sizes," Harvard Business Review, Jan-Feb. 1956, pp. 49-60; or Robert G. Brown, Statistical Forecasting for Inventory Control, (New York: McGraw-Hill Book Company, Inc., 1959).

[2] Stanford Research Institute, Advanced Stock Control Procedures, Electronics Supply Office, A report prepared for the Bureau of Supplies and Accounts, Navy Department, Washington, D.C. (Menlo Park, California: Stanford Research Institute, January, 1959), p. 48.

The total annual costs of ordering and holding the operating level of supply (the amount in excess of the stock held for insurance against stock-outs) can be expressed mathematically by the formula:

$$TAC_{op} = \frac{A}{Q} C + \frac{Q}{2} PI$$

where:

TAC_{op} = the total annual costs of buying and holding the amounts purchased.

A = the annual demand

Q = the "buy" quantity

C = order cost per order

$\frac{A}{Q}C$ = the cost of ordering the annual demand

and:

P = the unit price of the item

I = the holding cost rate.[1]

$\frac{Q}{2}PI$ = the annual cost of holding material in store.

---

[1] The holding cost rate (I) is sometimes incorrectly called the interest rate; however, as noted above the holding cost rate includes the sum of the obsolescence risk rate, the costs of physical storage, and the interest rate pertaining to the utility of funds which, if they were not used to finance the inventory would be available for other purposes. This might be shown symbolically as: $I = o + s + i$.

The economic order quantity (or economic "buy" quantity) is computed through expressing a relationship between the costs associated with holding material in storage and the costs associated with placing orders. Symbolically the economic order quantity formula could be written as:

$$Q = \sqrt{\frac{2AC}{PI}}$$

where:

Q = the economic order quantity
A = the annual demand in units
C = the cost to order for each order
P = the unit price of the item, and
I = the holding cost rate.

This relationship is expressed graphically in Figure 1. From this, it can be seen that ordering costs decrease whenever larger quantities are ordered since it will be necessary to place orders less frequently. On the other hand, as the quantity ordered in each purchase increases, inventories are increased; consequently the costs to hold the inventories in store increases. From Figure 1, it can be noted also that the minimum total annual costs would result if a quantity of 500 of the item were ordered;

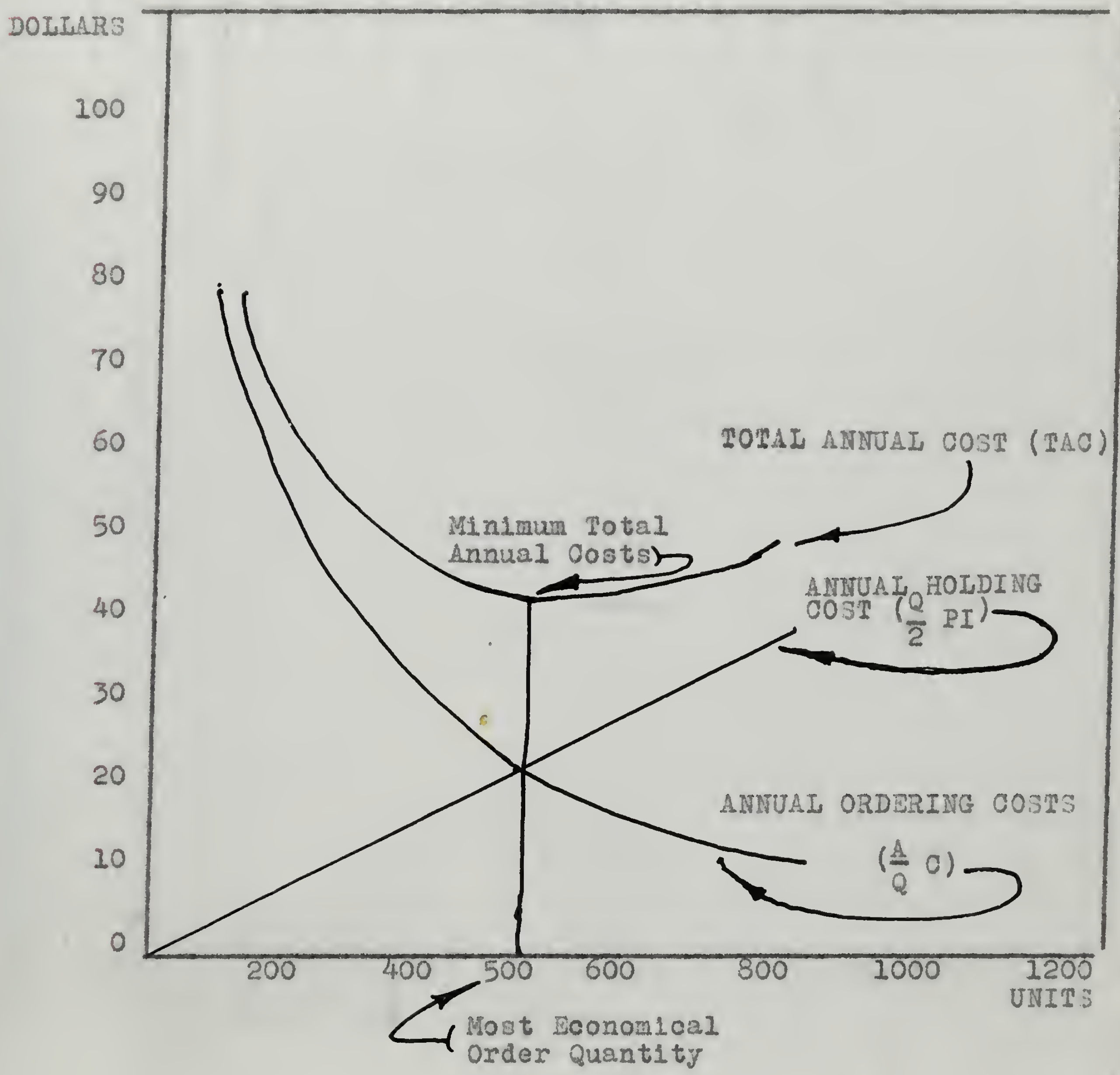
however, if a quantity of 400 or 600 were ordered costs would not increase significantly. This is because, at the points near the minimum total cost point, one of the costs involved decreases about as much as the other increases. This is one of the virtues of using the economic order formula. The last point to mention in connection with Figure 1 is whenever a large error is made in the computation of economic order quantities, total annual costs increase significantly. This is especially true if the quantities are reduced. The lower segment of the total cost curve can be seen to rise more rapidly.

In finding the most economical method of managing our inventories, the use of mathematical formula is necessary; in view of the resentment sometimes engendered whenever mathematical formulae are introduced, this is unfortunate. However, the concept is basic; the optimum (least cost) method of managing our inventories is a most desirable goal. If we are unable to attain that goal, at least we should select the best alternative available, a "better" (less costly) method. This is the same concept of economic analysis currently used in the selection of alternatives by the Secretary of Defense:

> To help predict the consequences of alternative policies and practices, we may use models on paper, models in our heads, models in the form of games, or simulation laboratories to represent the functioning of logistics systems. In any event, the alternatives should be considered in terms of economic criterion. We should look at these choices as problems of maximization in the face of constraints or, in less

FIGURE 1

Determination of the Economical Order Quantity (E.O.Q.)



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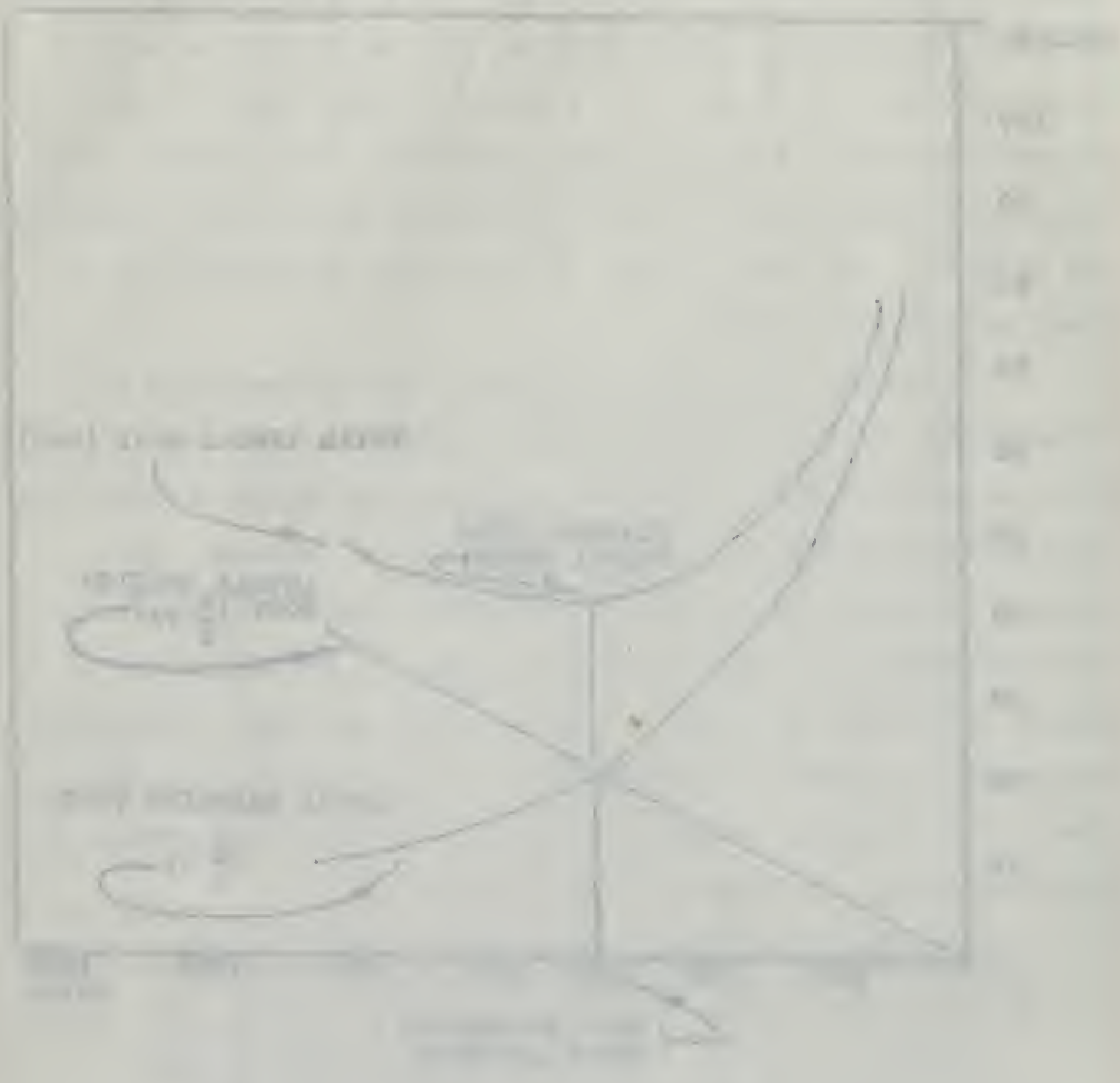

> technical language, as problems of getting the greatest capability from our limited resources. Again, the way of looking at these problems is what we wish to stress most of all. In addition, quantitative analysis . . . can often help us reach better decisions about these issues in logistics.[1]

With the development of these scientific decision rules, it is theoretically possible to compute the most economical quantities to be ordered simply by substituting the proper values for the costs involved in the formula and solving for Q, the economic order quantity. It is in the substitution of the proper values for the costs involved precisely where the difficulties lie. First, they are difficult to determine because they are so ephemeral. A less obvious difficulty arises from the fact that only the variable elements of these costs are significant to the computation and, to determine the variable elements, it is necessary to agree on an appropriate time frame of reference. What may be true in the long run may not be true, for example, from the annual budget point of view.

It is exactly this point which will be considered in some detail in the next chapter. It is recognized that at best the discussion can only point to an approach to the problems involved.

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[1] Charles J. Hitch and Roland N. McKean, The Economics of Defense in the Nuclear Age (Cambridge: Harvard University Press, 1960), p. 281. (Emphasis mine).

The solution of the problems involved in the determination of these costs has been the object of many years' effort by talented organizations. Even so, indications are that much remains to be done. The third chapter deals with two of the more current approaches to "fit" the formula to budgetary constraints, and recommendations with regard to these efforts.

In part, some of the discussion included will be applicable to the formula for determining the reorder point ("when" to order as opposed to "how much," which is the basis for the material in this paper). However, consideration of reorder points would involve a discussion of shortage costs (the price we pay for not having an item in stock where and when it is required), military essentiality (how important an item is to the mission of the ship), and supply effectiveness. Each of these concepts is important and is commended to future students as fruitful areas of research, especially as they relate to the funding of inventories. They are omitted only because of the additional time which would be required for their special considerations.

Limitations of Economic Order Quantity Formula

Although it is obvious to those trained in the science of inventory management, it should be recognized by all that the use of economic order quantity and variable safety limit formulae is based on the premise that any variation involved is of a random nature. This would include variation in usage and variation in

production (procurement) lead-time. If the requirement for an item is based on other than "normal" (including only random variation) demand, such as, for example, a "Cuban crisis," where all available ships were alerted and replenished with all items to endurance levels, then the scientific supply decision rules are not applicable. Many a supply officer has found himself in the position of being out of stock, for example, of enlisted men's neckerchiefs in his clothing store within a few minutes after the word "leaked out" that the new commanding officer was a "bear" on rolled neckerchiefs (rendering the well-creased neckerchiefs in the hands of the crew "obsolete"). Whereas the store normally sold from 20 to 30 a month on which the "normal" stock of 90 was based, suddenly 850 new ones were needed. It is important to recognize this point. If the demand for an item is based on other than random demand, the techniques involved in the economic analysis of military inventories are not applicable.

The Navy is faced with a twofold objective of military readiness and economical operation. These objectives, in a sense, are not compatible in that to increase the effectiveness of one reduces the effectiveness of the other. It can be argued that, if the Navy must be ready to meet whatever "crisis" arises, then the economic decision rules should not be utilized. However, for large segments of the Navy's inventory, the variation in demand approaches randomness to a degree that these rules have reduced inventory management costs without significantly detracting from

military readiness. In a study of these rules for a small segment of the inventory controlled by the Naval Supply Center, San Diego, the following was concluded:

> The new policy will make possible substantial improvements in supply system costs and effectiveness. . . . A conservative expectation is that the new policies will permit a permanent reduction in inventory investment of $100,000 (approximately 30 percent), a reduction in the number of reorders from over 11,000 to slightly under 4,000 (approximately 65 percent), as well as a significant reduction in the number of shortages (when compared with present procedures).[1]

One of the approaches to obtain efficiency in military decisions as proposed by now Assistant Secretary of Defense (Comptroller) Charles J. Hitch is by

> Increased recognition and awareness that military decisions, whether they specifically involve budgetary allocations or not, are in one of their important aspects economic decisions; and that unless the right questions are asked, the appropriate alternatives selected for comparison, and an economic criterion used for choosing the most efficient, military power and national security will suffer.[2]

The use of mathematical supply decision rules has significant implications. If they are used correctly, then the management of military inventories can be performed more

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[1] Robert F. McIntosh, Improvement of Local Supply Decision Rules at N. S. C., San Diego, A report prepared for the Bureau of Supplies and Accounts, Navy Department, Washington, D. C. Prepared by the Planning Research Corporation, Report PRC R-132 (Los Angeles: Planning Research Corporation, 1 October 1959), p. 25.

[2] Hitch and McKean, op. cit., p. 107.

economically without impairing military readiness. If they are used incorrectly, or when they are not applicable, unnecessary costs may be incurred. But, more important, the danger exists that while we may manage our inventories more economically, we do so only at the cost of sacrificing military readiness to a degree that is unrecognized in inventory management decisions.

CHAPTER II

THE DESCRIPTION OF COST PARAMETERS

General

By far the most difficult problem involved in the use of economic order quantity formula is the determination of the cost parameters. Some of the parameters, which on the surface seem relatively easy to determine, are in fact complicated by the many factors involved. For example, the annual demand must be forecast in terms of its replenishable (recurring) and its nonreplenishable (one-time requirement) nature. Frequently this is difficult to determine based on the records available at the point where replenishment quantities are being computed. It is necessary to treat nonreplenishable demand as known (planned) requirements; only the replenishable demand is subject to random variation. Many techniques have been devised to assist in forecasting annual replenishable demand. Many articles have been prepared with respect to forecasting. Random variation in demand can be predicted within set limits of confidence on the basis of probability formula. The use of past demand should not be deprecated as a method, for it very often is the best estimate of the future. But it is important to recognize that the computation

of the economic order quantity is a function of predicted demand--not past history. Known "J" factors which would affect the future recurring demand for an item must be made a part of the forecast. One technique used to assist in the determination of demand trends is the exponential smoothing technique which weights demand by giving more importance to recent developments. Another is the use of tracking signals to detect demand surges. Continued development of these techniques is encouraged to improve the validity of demand forecasts. After all, the decision rules are only important in that they affect future costs; these costs are a function of the predicted demand.

The problem of ascertaining the unit price parameter is not without difficulties. It is the unit price of the quantity to be ordered which is pertinent. At the time the decision is made to replenish this may not be known. Often it depends on the quantity to be ordered, especially if large quantities are involved. The cost of transportation is sometimes included in the price of the materials; at other times it is not.

While both the annual demand and the unit price parameters present some very important problems in computing the economic order quantities because of their relative simplicity as opposed to the others involved, most of the discussion will be centered on the ordering costs and the costs of holding material in store. One of the difficulties in determining these costs stems from the

fact that the present method of accounting for these costs does not facilitate segregation in the manner required. The second difficulty is,only the variable elements of the costs incurred are involved in a given computation. However, what may be a fixed cost in processing the next order, such as the additional purchasing clerk's salary, may, when viewed from the perspective of the annual budget, be a variable cost (the clerk could be released if enough orders were eliminated); in the long run, every cost is a variable cost.

The Cost of Ordering

Ordering costs increase, generally, as the number of orders increase. These costs include the salaries of the purchasing personnel, telephone bills, correspondence, telegrams, filing, processing of receipt documents, the cost of paying bills, of unloading facilities, transportation, drayage, inspection, receiving and initial warehousing. Strictly speaking, it should also include the manufacturer's setup costs; however, these costs are rarely known. They can be identified in any situation where intracompany shipments are made, such as in the military. When a requisition is placed on another depot, the additional costs incurred (by the shipping depot) include processing the incoming requisition, picking, packaging and shipping the item. It should be recognized that, while intramilitary requisitioning procedures

may be less costly than the cost of originating a purchase order to purchase from commercial sources, the double handling of the paperwork and material involved by the military more than offsets such economies.

It is difficult to determine the costs of ordering simply because of the manner in which costs are "hidden" in the appropriation structure and the "spillover" which results when one resource is committed to more than one function. For example, the Navy officer who has purchasing as one of the functions for which he is responsible is paid from the appropriation, Military Personnel, Navy. The first problem would be to allocate the variable portion of his pay and allowances--plus the other expenses involved in supporting him as a Naval officer--to the purchasing function. If his time could be apportioned, this would be a reasonable basis. In the very short run, of course, no variable element would be involved; all costs would be fixed. In the very long run, part of his time could be allocated as a variable cost. In a budget year concept, only a part of the long-run costs should be so allocated on the premise that the time of military officers involved in purchasing could be reduced if a sufficient number of purchase orders could be eliminated. Further complications arise in that some of the costs in supporting the military officer are paid from appropriations other than the appropriation Military Personnel, Navy.

By far the greatest portion of the ordering costs are paid from the appropriation, Operations and Maintenance, Navy. This includes the salaries of personnel and expenses of the ordering office, the salaries and expenses of the receiving personnel at the receiving activity, as well as the shipping costs of shipping activities when they can be so identified. A part of the cost of ordering may be paid for by the appropriation financing the material purchased. If shipping costs are added to the price of the material, the using activity pays the cost. When material is accepted at the contractor's plant, or is shipped between military activities, then the service-wide supply part of the appropriation pays the additional costs. The cost of construction of office, receiving, and shipping facilities is included in the appropriation, Military Construction, Navy. Some of the costs, such as the interest on the funds which finance the ordering costs, never appear in the Navy appropriation structure.

It can be seen from the above that, although some effort has been expended in determining the variable costs of ordering, the collection of these costs is difficult. Also, the variable portion of the costs increases as the time-frame is extended. This has resulted in considerable confusion in the implementation of the economic order quantity formulae. Several widely divergent estimates of the cost to order have been formulated. Most often the tendency is to underestimate the ordering costs as reported

in the Production Handbook.

> One company was surprised to find its cost of procurement per order was $21.11. A rule-of-thumb figure by other companies is in the neighborhood of $8.00 to $12.00 per purchase order.[1]

The Bureau of Supplies and Accounts recommended that a value of $45.00 per order be used by the Stanford Research Institute in its study of Advanced Supply Decision Rules for the Electronics Supply Office in 1959.[2] The Planning Research Corporation in its analysis of local supply decision rules at the Naval Supply Center, San Diego used an order cost of $5.40 per order.[3] It would appear the latter lower estimate was based on the fact that orders were placed for a relatively small segment of material involved in the study; also that relatively small orders would be issued for the material involved. One of the larger inventory control points has recognized the increasing complexity of contracting for larger dollar volume and has estimated the cost of large orders (over $2,500) as about $725, whereas the cost of small orders (under $2,500) was estimated at about $75 for the centralized procuring agency. When the Bureau

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[1] Gordon B. Carson, (ed.), Production Handbook, (Second Edition; New York: The Ronald Press Company, 1959), pp. 4-55.

[2] Stanford Research Institute, loc. cit., p. 22.

[3] McIntosh, loc. cit., p. 12.

of Supplies and Accounts stock tables were issued originally for certain categories of locally controlled material, the tables were based on an estimated cost to order of $10.00 per order. In a study of the ordering costs of one of the Navy's inventory managers, the Ships Parts Control Center, Mechanicsburg, Pennsylvania, line item order costs were determined to be $24.08 for small purchase orders, $41.89 for negotiated contracts, and $55.34 for advertised contracts. It is noted, however, that ordering costs for this estimate were relatively narrowly defined as only those costs incurred at Ship's Parts Control Center.[1]

That the estimates which have been cited are so widely divergent of necessity, points up the fact that they have been computed on differing ground rules. In the report of Dunlap and Associates, Inc., some of the problems involved are noted:

> First, any estimates of the parameters required must be wholly arbitrary because the underlying theory is not stated in operational terms. The theory does not define "order cost" and "holding cost" parameters. There is no way of telling what costs are properly chargeable to these parameters, or where they begin or end, or whether they are long-run or short-run marginal costs. Such questions can be answered only by making arbitrary assumptions.[2]

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[1] Dunlap and Associates, Inc., A Study of Procurement Costs at the Ship's Parts Control Center, A report prepared for the Advanced Logistics Research Division, Bureau of Supplies and Accounts (Stanford, Connecticut: Dunlap and Associates, Inc., 31 July 1961), p. 72.

[2] Ibid., p. 70.

To resolve the dilemma, for purposes of their study, the following was rationalized:

> Since the theory underlying the economic buy formula in use at SPCC has not been stated in operational terms, it is impossible to measure the "order cost" in a way which can really be justified in terms of the theory. The most that can be done is to make some arbitrary or intuitive operational definition of the term "order cost" and to measure it accordingly.[1]

Although there are difficulties involved in the determination of variable (short-run) costs, it by no means follows that no decisions should be taken. It is more difficult to estimate variable elements for short-run costs than for long-run costs. It seems reasonable that if the procurement operation were to be envisioned as one which would endure for a number of years, that as many of the costs as possible should be considered as variable costs in the determination of cost parameters. Not only would this reduce the complexity of cost analysis, but would provide for a more efficient long-run procurement effort. To view the costs always in terms of annual budgets would deny the long-run advantages of using economic order quantity formulae.

Obviously, there must be some agreement as to some time-frame of reference for the estimation of the variable elements of the costs involved. Further, if the estimates indicate that the

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[1] *Ibid.*, p. 71.

value of a cost parameter should be changed, these changes should be implemented on a progressive basis, since any revision of values will tend to, in the transient year(s), affect other cost parameters as well. Cost parameters must be studied in terms of the time, location, and other constraints involved and are by no means a one-time determination. In fact, the revision of a cost parameter will affect future determinations of its own value. However, it is concluded that we are not in a position to make sound inventory management decisions which will select economically attractive alternatives unless we know what our costs really are.

The way is not easy. Problems involving the same kind of determinations are faced in connection with the maximization of cost effectiveness in decisions at top governmental levels. Indeed, if anything, the problems there are even more difficult.

> Particular attention had to be given to the development of meaningful cost/effectiveness data on alternative weapons systems. Because of the long life cycle of major weapons systems, their costs must be projected over years--ideally over their entire life span. . . . Since such long term projections are very difficult with any degree of precision, we fixed on a five year period, which is short enough to make possible reasonably accurate estimates and long enough to provide a good approximation of the full cost.
>
> Additionally we needed to know, not only the one-time costs for development, procurement and construction of facilities, but also the recurring annual operating costs.[1]

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[1] Charles J. Hitch, "Management of the Defense Dollar," Navy Budget Digest, Fiscal Year 1963, (Washington: Office of the Comptroller, Navy Department, 1962), p. 22.

The Holding Cost Rate

The holding cost rate is possibly the most difficult cost parameter to determine. This is difficult not only because of the lack of accounting data relative to the variable cost elements, but also because of the three types of costs involved. The three costs included in the holding cost rate are the costs of physical storage, the obsolescence risk rate, and the interest rate.

The costs of physical storage include warehousing, heat, light, rent, refrigeration, dehumidification, janitor service, security, preservation, and the cost of physical inventories. When long-run costs are considered within the variable portions, there are further problems of allocating costs of materials handling equipment, warehouse bins, and the other fixed assets which are eventually required to handle additional material. Of the estimated costs of holding inventories, these costs are more easily computed in a long-run analysis. They become increasingly difficult when computed on an annual basis. Two of the economic costs of holding inventories which are difficult to justify when military inventories are considered are insurance costs and the loss of taxes.

While the Navy does not pay for insurance, the fact is that it does sustain losses for which a prudent businessman would obtain insurance. This is not to say the Navy is in error by not obtaining insurance; this cost is included as a recognition of the losses sustained which are normally insurable. The loss of taxes

is even more difficult to justify, however. The cost of taxes would be recognized by a businessman. If the material in store for the government were not required, and these resources could be diverted to industrial uses, then the government would be able to realize a return from taxation. This return is lost because the government has diverted these resources to public use. This return is lost to the government and, in this sense, is an "economic cost" of holding the material by the government.

The obsolescence risk rate is measured by a number of costs. It may take several forms, including (1) outright spoilage after a more or less fixed period; or (2) risk that a particular unit of stock will become unsalable for technological reasons. Some items in the supply system have a definite shelf life, such as photographic paper, rubber goods, or fresh produce. Also in military inventories it is often necessary to store items under other than ideal storage conditions. The humidity in one area, extreme cold in another, or necessity for outside storage in another, all may increase spoilage and deterioration. The obsolescence of material in store, particularly of repair parts, is probably one of the most significant elements of the cost of holding material in military inventories.

Because of changes in technology and operating concepts, items in the system are being constantly replaced by more advanced designs. Although those items having a replenishable demand, and therefor susceptible to scientific supply decision rules, are less

affected than others, this has increased in importance with recent technological developments. Whole new weapons systems are being made obsolescent, although, in general, the costs "sunk" in the old weapons systems are considered before they are phased out. The importance of this element is stressed simply because it is so often underestimated. As an example, in the budget presentation of the Bureau of Supplies and Accounts with respect to the apportionment of the Naval Stock Fund allotment of the Ships Parts Control Center at Mechanicsburg, Pennsylvania, it was estimated that 18 and 24 percent of the repair parts originally provisioned for new equipments for the fiscal years 1962 and 1963, respectively, would become obsolete without ever having been used.[1]

Possibly the most difficult of the costs to consider is the interest rate to be used in the computation of inventory requirements. The Department of Defense Instruction 4140.11 specifies that an interest rate of four percent will be used for inventory management purposes, based on the concept that the U. S. Government pays about that rate; therefore, this is one of the factors used in determining the holding cost rate. However, at such times as funds are restricted on a temporary basis, a higher rate of interest might be justified by the inventory manager or the

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[1] Bureau of Supplies and Accounts, Navy Stock Fund, Fiscal Year 1963 Reapportionment and Fiscal Year 1964 Budget Estimates (Washington, D. C., Bureau of Supplies and Accounts, 1 October 1962), p. 82.

Defense Department, on the pretext that if the money were not used to finance inventories, it might be used elsewhere more productively. When the use of funds is delayed, that is, when the funds are used elsewhere with the understanding that a larger amount will be made available at a later date, and a higher interest rate is used, the manager is said to be expressing his "time-preference rate."

> Time-preference rates express one element of choice in decision rules for a complex system. It is the choice of one from a set of alternative time patterns of benefits and costs expected in successive future periods. Where there are a number of such patterns or distributions over time that are all feasible, a common way to proceed is to consider only that subset where the importance of benefits (such as meeting demand) is assumed to decline either linearly or exponentially (analagous to simple or compound discounting) in successive future years. Each alternative pattern within this subset can then be characterized by its rate of decline.[1]

One interesting study was made by the Planning Research Corporation in which the thesis was advanced that if it were unnecessary for the government to hold inventory, the funds used to finance the inventory could be used for industrial purposes; hence the "interest" rate which is comparable is the average rate of return

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[1] Navy Department, Advanced Logistics Research Division, Bureau of Supplies and Accounts, What is Time Preference Rate? (Washington, D. C.: May, 1960), p. 16.

on investment in the American economy.[1]

Following this thesis, in order to determine the average yearly rate of return, earnings for 72 industrial corporations and the yearly asset values (less cash and receivables) were aggregated. The total ten-year earnings (1949-1958) were divided by the sum of the year-end asset values to determine the average yearly rate of return. The companies included manufacturing, electric and natural gas utilities, telephone communications, and railroads. The results are tabulated as follows:

Industrial Sector	Physical Assets (Billions of dollars)		Average Annual Rate of Return
	1949	1958	
Manufacturing	76.7	164.0	19.6
Utilities	17.8	42.6	10.2
Telephone Communications	7.3	17.2	14.0
Railroads	26.0	32.8	7.9
Totals[2]	145.6	299.8	

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[1] J. A. Stockfisch, The Interest Cost of Holding Military Inventory, A report prepared for the Bureau of Supplies and Accounts, Navy Department, Washington, D. C. (Los Angeles: Planning Research Corporation, PRC R-156, 5 May 1960), p. 4.

[2] The totals shown are those which are included in the report (page 11), although they are incorrect. The error arises in that, in the report, utilities were broken down into electric and natural gas. The subtotals for utilities were added in a second time, hence the totals shown are overstated by 17.8 in 1949 and 42.6 in 1958. The correct totals are 127.8 and 257.2, respectively.

When percentage weights are applied, based on the percentage of each sector of the economy, the overall rate of return generated by investment in physical assets turns out to be 16.5 percent.[1]

There are a number of points that might be made which would reflect on the validity of this analysis. Some of these include the fact that only a relatively few of the larger corporations were used as a basis for the analysis. The smaller companies, bankrupt corporations, and the entrepreneurs are not represented. To include the noncorporate sector in the calculation would lower the rate of return somewhat, although not much since the larger sector, in terms of assets committed, is the corporate sphere. The "book value" of assets, which was used as a base for the computations, also does not accurately reflect their true economic value because of the deflated value of the dollar and the method of depreciating "old" assets. To verify the percentage of return on investment, a second method was utilized. The market value of outstanding securities of the 72 companies was used to value their corporation's assets as measured by the market. The market value was then divided into the income which accrued to these security holders. Several adjustments were necessary to refine the results attained. The results of the survey were as follows:

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[1] _Ibid_., p. 14.

Average Annual Market Value of Assets (Millions)	Average Yearly Income Before Taxes (Millions)	Rate of Return
$61,821.3	$8,604.1	13.9%

This is comparable to the 19.6% rate of return derived from the first method. The first method deducted cash, near-cash, and receivables, on the grounds that they were nonproductive in the social sense and to include them would have been double counting, whereas the second method included them. If all assets had been used in the first method, the percent rate of return also would have been 13.9%, identical to the rate of return obtained by the second method.[1]

It is a matter of conjecture to consider that the next $60 billion invested in the economy will bring the same rate of return as did the previous $60 billion. Further, it must be observed that the market value of stock can vary overnight without a significant corresponding reduction in assets. It would be another victory for "techniquemanship" were one to succumb to the statistical accuracy portrayed by the above data. But it is concluded here that the four percent set by the Department of Defense as the appropriate rate of interest in the aforementioned Department of Defense instruction does not adequately reflect the rate of return which might be realized if the alternative to

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[1] _Ibid_., p. 18.

investment in military inventories was investment in industrial assets. Although this alternative is not available insofar as the individual military inventory manager is concerned, the alternatives which are available compete for every other defense dollar, and in sum total the rates paid for military inventories are the same as for missiles or any other expense. Total government dollars must compete with the alternative uses which might be made of that dollar provided it were not collected in taxes. This is the point of view presented in Chapter III of _The Economics of Defense in the Nuclear Age_:

> What, in a fundamental sense, is the "cost" of a course of action? It is whatever must be given up in order to adopt that course, that is, whatever could otherwise be kept or obtained.[1]

While it is contended that the four percent figure is unrealistically low in determining appropriate cost parameters, if the 13.9% were used as an "interest" rate, then the holding cost rate would become extremely high when added to an obsolescence rate and actual rates of storage costs. If a ten percent obsolescence rate were applicable and a physical holding rate of 1 percent were used, then the holding cost rate would approximate 24.9%.

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[1] Hitch and McKean, _op. cit._, p. 26.

With the variables involved in the holding cost rate, it can be seen that each inventory manager is hard pressed to arrive at any meaningful rate which best relates his experience--and the experience of the supply system--to his particular range of items. Some guidance has been provided by industrial concerns which, from a profit motive, have devoted considerable time and energy to the study of this problem.

Generally, the total of the holding costs runs from 10 to 20 percent of the value of the inventory per year. One large automotive manufacturer with a model obsolescence problem uses 25% per year as his figure.[1] One commonly used estimate of the percentage cost per year of carrying inventory is as follows:

Storage facilities	2%
Taxes and Insurance.	1
Material Handling and Record-Keeping	4
Interest on Investment	5
Depreciation, Obsolescence, and Shrinkage	5
Total	17%[2]

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[1] Carson, op. cit., pp. 4-58.

[2] Ibid.

Another manufacturer computes costs at 15.75% to which he adds another contingency factor of 20%. He has recently reduced his contingency factor to 10% and contemplates even further reduction.[1]

> Bechtel (NACA Bulletin, vol. 36) states that "in the American Cyanamid Company, they made numerous studies to determine the cost of carrying inventories and each time came up with a different set of figures. The reason was that the different sets of inventories involved different sets of costs-to-carry, since different types of items require different types of costs. They found that a range of 12 to 20 percent of the annual inventory valuation was an appropriate cost, with the lower standard applying to standard goods such as bulk acids, alums, fertilizers, etc., which did not deteriorate or go out of date".[2]

Bechtel states that "a recent calculation was made to show the estimated annual average cost of carrying inventories by U. S. industry. . . . If a 5 percent interest rate were used, it would increase the carrying cost to 22 percent per year."[3]

It would seem then, that the higher rate would be more applicable to an inventory of items such as ships repair parts where there is a relatively high obsolescence risk. In a study by the Stanford Research Institute of items controlled by the Electronics Supply Office, a holding cost rate of 15% was used. This was based on the following valuation:

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[1] *Ibid.*

[2] *Ibid.*

[3] *Ibid.*

Physical Holding Rate	1%
Interest Rate	4
Obsolescence Rate	.10
Total Holding Cost Rate	15%[1]

The Bureau of Supplies and Accounts, after some study in the matter, concluded that this area was one in which there was a need for further study. But in order to comply with Department of Defense directives, stock tables were published in 1959, to be utilized on a restricted basis for locally controlled material in which reorder quantities were computed using a holding cost rate of 20 percent. Other Bureau of Supplies and Accounts stock tables have been approved for use, using a holding cost rate of 20 percent, so that as of 1 August 1962, approximately twenty percent of the Navy inventory, or 250,000 items, are now controlled on this basis.[2] The 20 percent holding cost rate was used simply as a matter of expediency; however, to date no further studies are underway which seek to verify the accuracy of the percentage. Overall, it appears to be a reasonable compromise, and yet this is the very area in which the inventory managers are subject to criticism in the justification of their budgets. Whereas the holding cost rate of

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[1] Stanford Research Institute, loc. cit.

[2] Alan J. Gradwohl, Technical Description of the BuSandA Stock Table Program. A report prepared for the Bureau of Supplies and Accounts, Navy Department, Washington, D. C., Report PRC R-262 (Los Angeles: Planning Research Corporation, 1 August 1962), p. 1.

20 percent would tend to reduce the investment in inventories, as opposed to the rates which would be used if the 4 percent interest rate were used as recommended by the Department of Defense, budget analysts have suggested the use of even higher rates, as much as 300% in order to reduce investment levels even further. Unfortunately, while a small increase in the holding rate would not affect total costs significantly, such a large variation is very costly. It is difficult to prove that costs are increased, however, when the true economic order quantity depends on the accurate evaluation of the cost parameters in the first instance. One not only has difficulty justifying budgets, but really cannot know if, in fact, his budget estimates are truly optimal from a cost point of view.

CHAPTER III

ADJUSTING INVENTORIES TO BUDGET LIMITATIONS

Budget Justification

The purpose of the scientific inventory decision rules to reduce the total costs of inventory management to a minimum, would seem the answer to the budget analyst's prayers; yet the facts are that insufficient funds have been authorized to permit ordering the "most economical" order quantities. Ideally, the justification of the inventory manager's budget would follow the procedure of determining the most economical costs, compute requirements based on the formula, total the costs of obtaining these requirements, and budgeting for these funds. Unfortunately, there is considerable discussion regarding the accuracy of the cost parameters as has been suggested in Chapter II. Then, of course, the costs are absorbed by various appropriations and this requires review by more than one budget analyst. It is not uncommon to have one appropriation cut on the assumption that it will be funded from another only to have the second budget analyst fail to consider the increase proper in the appropriation which he reviews. If the Navy inventory managers are to realize the full benefits from using the

economic order quantity formula, there must be a correlation of effort to balance funds properly used to finance the purchase of the material (i.e., the Navy Stock Fund) and the funds used to finance inventory operations (i.e., Operations and Maintenance, Navy). In describing this phenomenon, Department of Defense Comptroller Hitch points out:

> . . . cheap parts can economically be stocked in greater number and quantity at base level than has been the case under Air Force regulations. Various statistics confirm this view. About 25 percent of all aircraft parts demanded at a base during a month are not now normally stocked at a base or are not stocked in sufficient quantities. . . . It is not very hard to prove that it would be economical for the Air Force to keep larger stocks of cheap aircraft spares at its bases and to reorder in larger quantities than in the past. This need not mean an equivalent increase in Air Force worldwide stocks--far from it--but it does involve some shift of funds away from depot supply operations.[1]

While there are potential savings in the full implementation of economic order quantity formula, there are transition costs which must be considered. In the early stages it is necessary to order the more inexpensive items in larger quantities, temporarily increasing the investment costs. While in full implementation these increased costs would be offset by reduced stock levels of the more expensive items, there is a natural "reluctance" to accept lower inventory levels of these items. However, once this is accepted as a more efficient utilization of resources, this

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[1] Hitch and McKean, op. cit., p. 274.

should offset sufficiently to reduce inventory investment. Some of the problems involve the rate of interest established by the Department of Defense. The interest rate is so low that it has resulted in a relatively low holding cost rate. This would tend, in computing economic order quantities, to increase the level of investment. Computations thus far have resulted in inventory levels higher than the budget analysts of the Department of Defense have been willing to approve.

It is sometimes considered relatively simple in a revolving fund arrangement (i.e., where the fund is reimbursed by other appropriations whenever material held in the fund is issued) to utilize the funds generated for replenishment purposes. This would be a form of "backdoor spending" which Congressional appropriation committees find so reprehensible. However, in the case of the Navy Stock Fund, control is maintained over the cash portion of the fund through the budget by both the allotment and apportionment procedures. Each year the inventory manager must estimate his requirements and submit them in budget form to the Bureau of Supplies and Accounts, where they are consolidated and submitted through regular budget procedures similar to the method used for other budget requests. The requirements of the inventory manager are based on projected sales (issues), programs which must be supported, resources on hand, and stockage objectives which are set forth by the Department of Defense. Currently, for retail items of the Defense Supply Agency, stock levels authorized for the

Navy are a one and one-half month operating level (corresponding to the amount which is susceptible to replenishment by economic order quantity (E.O.Q.) and a one month safety level. For ship repair parts, the operating level of supply is six months' usage and the safety level three months' usage. However generous these levels may seem, there are many items in the inventories of repair parts which, although provisioned initially, never generate a demand which would justify replenishment on an economic order quantity basis.[1] Also, many items are maintained for "insurance" purposes, whether for mobilization purposes or other contingencies.

These factors present the problem which faces most inventory managers. Funds available are inadequate for the various programs supported, to provision new equipment, and to replenish stock for those items used. One method used to reduce requirements is to increase the interest rate used in the replenishment formula. This then increases the cost of holding the inventory and thus reduces the quantities to be purchased. A second method is now in use in which the cost parameters are not "adjusted." The "buy" quantities are reduced by an arbitrarily set percentage as necessary to reduce purchases to the levels permitted by available funds. The effects of these adjustments will be discussed in later sections, but assuming that the cost parameters were valued correctly, theoretically unnecessary costs will, in the long run, be incurred in both instances. These costs will not appear in the Navy Stock Fund. They will be absorbed primarily by the operations

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[1] *Supra*, p. 1.

and maintenance appropriation. Some of these costs will never appear in the accounting records or be identified with inventory decisions. The manner in which the costs increase will be discussed later, but as noted, this is difficult to ascertain with the dilution of fiscal charges as collected in the accounting system.

Adjustment of Cost Parameters

When the formula for the computation of the economic order quantity is considered, it can be seen that relatively large adjustments in the cost parameters will have little effect on the quantity to be ordered. In fact, this has been propounded as a virtue of the formula: exact determination of cost parameters are not essential to achieve many of the benefits of E.O.Q.[1] The formula is recalled:

$$Q = \sqrt{\frac{2AC}{PI}}$$

With the relationships involved, it really makes no difference whether the order cost is doubled or the holding cost rate cut in half; the results are the same. Further, since the order quantity varies proportionately to the square of the parameters

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[1] Economic order quantity. *Supra*, p. 4.

involved, it takes a rather substantial adjustment to affect the "buy" quantity. For example, increasing the holding cost rate fourfold is necessary to reduce the buy quantity by 50%. If it is desired to reduce the "buy" quantity the problem resolves into which of the cost parameters is most susceptible to adjustment and how much of an adjustment should be made.

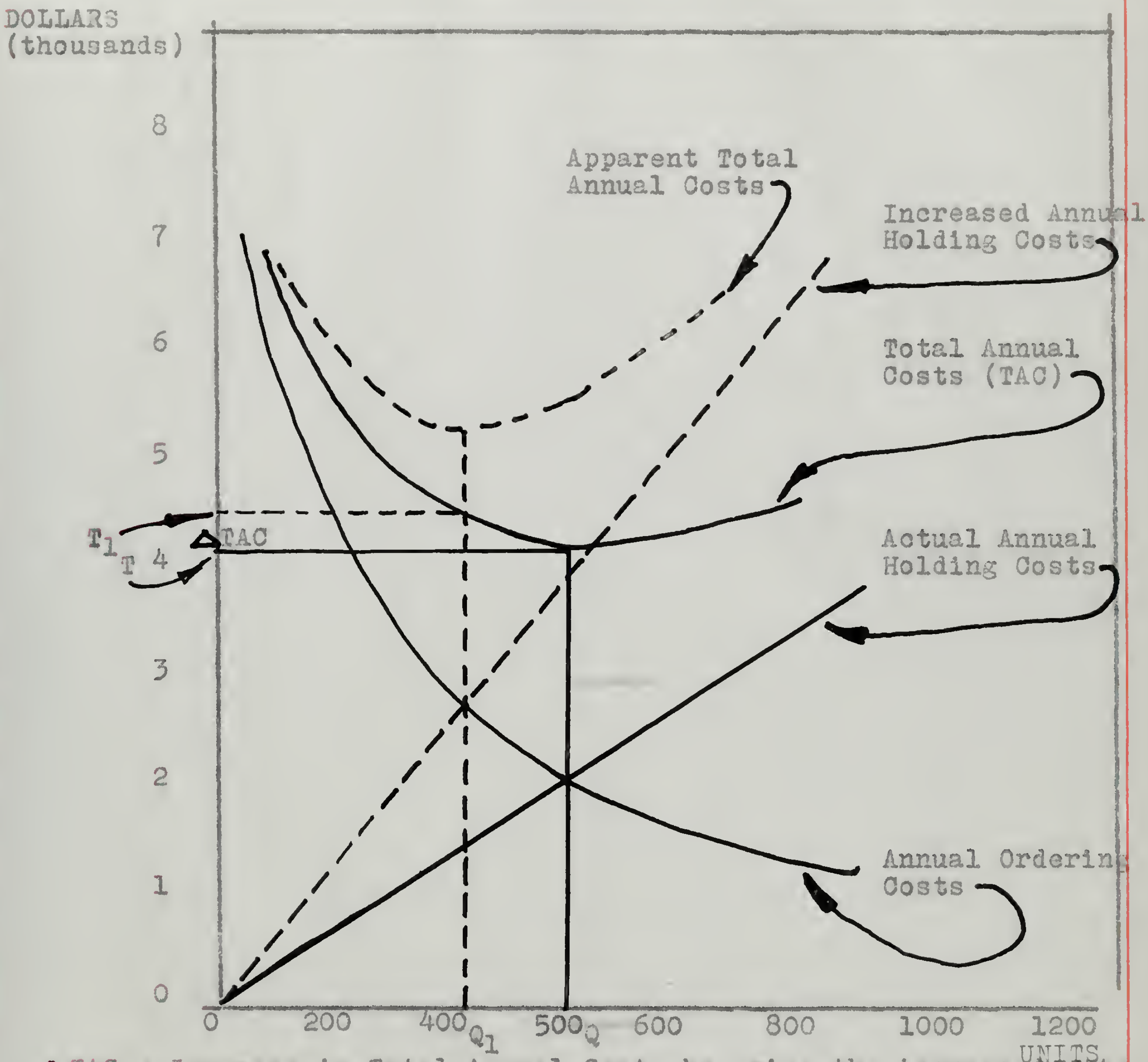
First, quite arbitrarily, the annual demand or the order costs might be reduced (A and C in the numerator of the fraction). The same adjustment can be made by increasing the unit price or the holding cost rate (P and I respectively in the denominator of the fraction). Two of these parameters are more difficult to adjust simply because they are more readily computed by reordering personnel. These include the annual demand, as reported, and the unit price at which the material is carried. Ordering costs and holding cost rates, because of the difficulty in computing them, are more readily adjusted. Since it makes no difference whether the ordering costs or the holding cost rate is adjusted, the same rationale might be used to eliminate adjusting the ordering costs. Of the two, the holding rate is susceptible to the greatest error in computation. Since it is more difficult to compute, it is more difficult to disprove an incorrect rate. Further, it is recalled that one of the elements included in the holding cost rate is the interest rate. The rationale which is used to increase the interest rate, as opposed to the storage costs or the obsolescence risk rate, follows the line that in strictly economic terms, whenever money is

scarce, it commands a higher rate of interest. Whenever this rate is increased, the new buy quantity is less than the true economic order quantity--assuming, and this is where the trouble lies, that the cost parameters were correctly determined in the first instance. Graphically, the results of increasing the interest rate are portrayed in Figure 2. It can be seen that, if the cost parameters were determined correctly in the first place, total costs in the example increased from $4,000 to about $4,400, presumably an uneconomical expenditure of $400. A second point to observe from Figure 2, is that even though the reorder quantity was cut twenty percent, because of the relatively "flat" contour of the curve near the minimum point, total costs increased only approximately ten percent. It can be also noted, however, that as further adjustments of the interest rate are made in the same direction, total costs will increase significantly.

Possibly the most misleading part of the graph is the top line, the apparent total annual costs line. It would appear that even with the increased interest rate, the buy quantity computed would result in the most economical operation--which is not true. The "aura" of economy which is imparted to the unwary does not in fact exist. Conversely, if the cost parameters are not computed accurately in the first place, this same aura of scientific analysis may be present, when in fact, true economy is not attained. Thus, the inventory manager can be misled into supporting a position in his budget justification when that position is untenable.

FIGURE 2

Effects of Adjusting the Interest Rate on the Computation of Economic Reorder Quantities



ΔTAC = Increase in Total Annual Costs by using the increased rate of interest.

Q = Economic Order Quantity (500)

Q_1= Buy Quantity using the increased rate of interest (400)

T = Minimum Total Costs ($4,000)

T_1= Total Costs using increased rate of interest. ($4,400)

[illegible]

[illegible]

[illegible]

Many attempts have been made arbitrarily to adjust cost parameters to achieve a portion of the desired results (i.e., a decrease in the level of inventory investment). In general, it has been found that the results of these have been difficult to rationalize and have not held up under analysis. In one such case it was decided that the safety level of certain categories of material could be reduced from the 99.9% level of effectiveness which resulted when the predetermined parameters were used. The shortage cost (the additional costs incurred by running out of material) was cut to one-half of the previous value. Stock levels were then lowered without a significant lowering of effectiveness. In another instance, the unit ordering costs used were significantly lower than those previously determined. This was justified on the basis that the number of orders decreased the operating level investment hopefully enough to "pay for" the increase in operating costs which resulted from using the advanced supply decision rules with the lower order costs. However, this adjustment is at variance with what might be experienced with a decrease in the number of orders; the unit order cost would tend to rise. At least a part of the unit order costs are fixed and semi-variable. Fortunately, the reduced order costs were not introduced into the Navy supply system. A research team, working with the problem of reducing investment levels to meet budgetary restrictions, attempted to explain the management implications involved as follows:

> What are the implicit assumptions behind the parameters suggested . . . compared, say, to the (original) parameters . . . ? First one can deduce the assumption that it costs one-fifth as much to requisition (one type of) material as (another) and one-twenty-fifth as much as (a third type). Since this assumption cannot be supported by outside data, one must next assume that the holding cost is five and 25 times as great for the other material. Now the twenty percent holding cost for (one type) can be broken down as follows--storage rate 1%, time-preference rate 14%, and obsolescence rate 5%. To increase the holding rate for the four (types) under consideration by varying the obsolescence rate would result in an obsolescence rate of 85% per year for (the one), and 485% for (the other type). These high values seem no more reasonable than a very low ordering cost for these (types).[1]

Also:

> Comparison of shortage costs reveals the implicit assumption that shortages in (one type of material) are one-fifth as important, and one-tenth as important in (another type), as in (the third type). Studies of essentiality of items aboard submarines suggest that electronics items may be categorically less essential than ships parts and ordnance items. There are, however, no studies to indicate that uniforms and lubricants are one-fifth as important as general stores items.
>
> Thus, to avoid increasing investment in each of the individual nine types of material under investigation we have had to make implicit assumptions about order cost, obsolescence, and essentiality which are neither completely logical nor supported by known studies.[2]

This is also noted in a study of ordering costs at the Ships Parts Control Center, Mechanicsburg, Pennsylvania:

> Another example is that with economic order quantity rules the amount of money to be spent on stock purchases is dependent upon the ratio of the "order cost" parameter to the "holding cost" parameter, which may be more or less than the amount of money available. Therefore, "order

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[1] Report of a Simulation of the Use of New Replenishment Rules at Navy Secondary Stock Points with Recommendations for Installation of the Rules, A report prepared for the Bureau of Supplies and Accounts, Navy Department, Washington, D. C. (Los Angeles: Planning Research Corporation, April, 1962), p. 25.

[2] Ibid.

> cost" and/or "holding cost" are adjusted to stay within the budget and, thereby, lose any resemblance to measures of resource utilization (i.e., costs). Many other factors continually force decision-makers to modify the rules, so that their resemblance to the rules originally formulated is more apparent than real.[1]

It seems as if the authors have noted the fallacy that, in arbitrarily adjusting the cost parameters, we have attempted to make the circumstances fit the system rather than design a system that would be responsive to the needs of management. We are cautioned by one leading authority in this respect when he discusses scientific management techniques per se:

> In fact, we may be developing a "gadget bag" of techniques for the efficiency expert instead of a management science which supplies knowledge, concepts, and disciplines for the use of management.[2]

There have been attempts to determine the losses which would result if incorrect data were used. Mr. Joel Levy approaches the problem in a technical paper by "assuming" correct parameters and then discusses the technical procedure which would be used for computing the losses which would result if other values were used.[3] This is a recognition by Mr. Levy of the difficulties involved in the determination of the "correct" parameters. Nevertheless, it is

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[1] Dunlap and Associates, Inc., loc. cit., p. 71.

[2] Peter F. Drucker, "Thinking Ahead," Harvard Business Review, January-February, 1959, p. 25.

[3] J. Levy, "Loss Resulting From the Use of Incorrect Data in Computing an Optimal Inventory Policy," Naval Research Logistics Quarterly, March, 1958, p. 75.

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[illegible]

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believed that we must make our best effort to ascertain these parameters. Once determined, their arbitrary adjustment to effect a reduction in order quantities will only serve to confuse and mislead the inventory manager. It is concluded that the method described in the subsequent section is preferable to reduce quantities ordered. The cost parameters, as determined by proper cost analysis, should remain as guideposts for inventory management decisions.

Reduction of Economic Order Quantities

The adverse effects which have been experienced by adjusting cost parameters, not the least of which is the loss of confidence by budget analysts in the economic order quantity formula. This resulted in the adoption by at least one inventory manager, the Commanding Officer of the Ships Parts Control Center, of another approach. The concept was derived that rather than "adjust" cost parameters, they would be computed as accurately as possible in accordance with long-range plans and so far as possible within limitations set down by higher authority. After the economic reorder quantities were computed, each one would be reduced by whatever percentage was necessary for the Commanding Officer to stay within the amount of Navy Stock Fund money allotted. The formula (introducing lambda as the percentage factor) is written:

$$Q_y = \lambda\sqrt{\frac{2AC}{PI}}$$

where all factors remain as originally described except that:

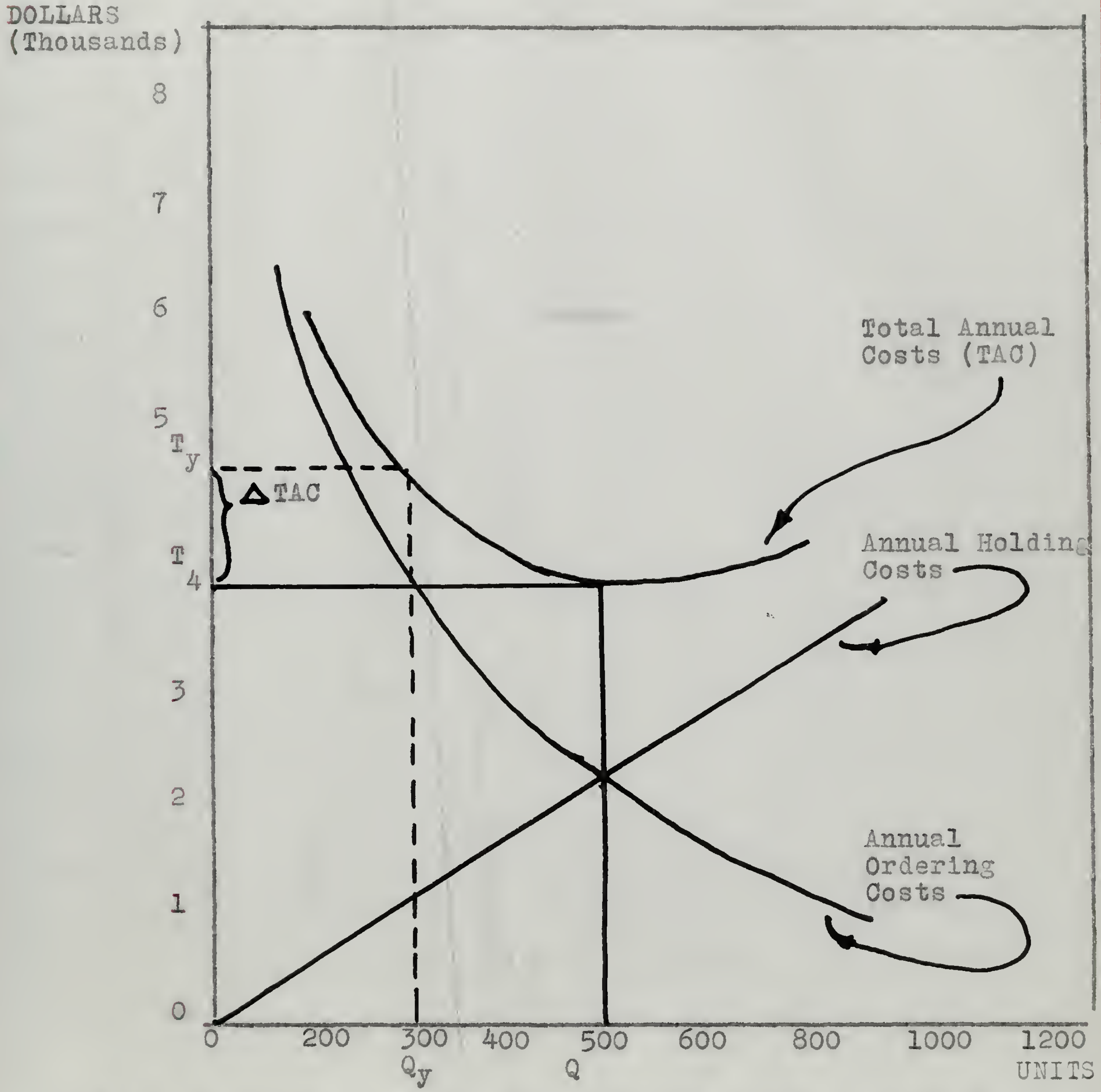
Q_y = the reduced "buy" quantity, and

λ = lambda, the percentage of the economic order quantities for which funds are available.

This, in this computation, the "true" economic order quantity can be computed as reduced by the value of lambda. The increase in total costs incurred as a result of insufficient stock fund can then be derived. The effects of this procedure can be shown graphically as in Figure 3. The advantages of this procedure lie in the fact that, once cost parameters are determined, the increased costs of ordering reduced buy quantities can be determined. The increased cost data might be submitted to justify budget requirements, and with proper data to support determination of cost parameters the inventory manager would be in a more sound position to justify budget requests. Further to illustrate the effects on total costs resulting from the application of various values of lambda, the Ships Parts Control Center, Mechanicsburg, Pennsylvania selected a sample of the items under their inventory management control and, by computer simulation, determined the effects on total costs as discussed in the next section.

FIGURE 3

Effects on Total Annual Costs of Ordering Reduced Buy Quantities



Δ TAC = Increased in total annual costs resulting from buying reduced quantities. ($800)

Q = Economic Order Quantity (500)

Q_y= Reduced Buy Quantity (300)

T = Minimum Total Annual Costs ($4,000)

T_y= Actual Total Annual Costs ($4,800)

Analysis of Costs, SPCC, Mechanicsburg, Pa.

To determine, in a specific example, the effect on ordering costs, holding costs, and total annual costs, these costs were simulated for a sample of the inventory under the control of the Ships Parts Control Center, Mechanicsburg, Pa. The method of sample selection is shown in Appendix I. The sample selected represents one percent of all the items controlled, less the items with no demand, since these items would not be replenished. This resulted in a total of 947 items for which there has been some movement; only Navy Stock Account items are included, there being only a few Appropriation Purchases Account Items involved. An average ordering cost of $25 and a holding cost rate of from 10 to 38 percent was used. The variation in holding cost rate depends on the obsolescence risk rate assigned to the items included. The obsolescence risk rate varies from 5 to 33 percent; the interest rate used is the Department of Defense directed rate of 4 percent, and the storage cost percentage used was one percent.

The results of the simulation are shown in Table 1. In this analysis, economic order quantities would be ordered for the sample items when lambda was assigned a value of 1; that is, its value would not affect the computation of the quantities to be ordered in the solution of the E. O. Q. formula. From Table 1, based on the cost parameters used by the Ships Parts Control Center, the minimum total annual costs for ordering and holding

TABLE 1

TOTAL ANNUAL COST ANALYSIS FOR 947 ITEM SAMPLE OF SPCC, MECHANICSBURG, PA. INVENTORY SUBJECT TO E. O. Q.

Lambda	Sum of Ordering Costs	Sum of Holding Costs	Sum of Total Costs[1]	Increase in Total Costs[1]
0.1	$290,921	$ 2,909	$293,830	$235,646
0.2	145,460	5,818	151,279	93,094
0.3	96,974	8,727	105,702	47,517
0.4	72,730	11,636	84,367	26,183
0.5	58,184	14,546	72,730	14,546
0.6	48,487	17,455	65,942	7,758
0.7	41,560	20,364	61,925	3,740
0.8	36,365	23,273	59,639	1,454
0.9	32,324	26,182	58,507	323
1.0	29,092	29,092	58,184	0
1.1	26,447	32,001	58,449	264
1.2	24,243	34,910	59,154	969
1.3	22,378	37,819	60,198	2,014
1.4	20,780	40,729	61,509	3,324
1.5	19,394	43,638	63,033	4,848
1.6	18,182	46,547	64,730	6,545
1.7	17,113	49,457	66,570	8,386
1.8	16,162	52,366	68,528	10,344
1.9	15,311	55,275	70,587	12,402
2.0	14,546	58,184	72,730	14,546
2.1	13,853	61,093	74,947	16,762
2.2	13,223	64,003	77,226	19,042
2.3	12,648	66,912	79,561	21,376
2.4	12,121	69,821	81,943	23,758
2.5	11,636	72,730	84,367	26,183
2.6	11,189	75,640	86,829	28,644
2.7	10,774	78,549	89,324	31,139
2.8	10,390	81,458	91,848	33,664
2.9	10,031	84,367	94,399	36,215
3.0	9,697	87,277	96,974	38,789

[1] Values taken to the next lower dollar; totals will not necessarily be in agreement due to rounding off.

these items is $58,184. Presumably, for the entire universe, the minimum total costs for ordering and holding the inventory is approximately $5,818,400.[1] This sum would be equally divided as between ordering and holding costs, since by definition, total costs are at a minimum when they are equal. Total annual costs, ordering costs and holding costs are shown in Table 1 for the values of lambda from = 0.1 to = 3.0.

An interesting observation is that total annual costs increase at a much greater rate as the buy quantities are reduced than they do as they are increased. The analysis shows that if order quantities are decreased by 50% (Lambda = 0.5) the increase in total annual costs is $14,546 for the sample items. On the other hand, the increase in annual costs when the order quantities are increased by 50% over the E. O. Q. (Lambda = 1.5) is $4,848, or about one-third. This difference increases at an ascending rate the more the order quantities are adjusted. It would appear from this, that if an error were to be made, it would be more advantageous from a total annual cost point of view for the error to be made on the high side (ordering greater quantities). Unfortunately, when the matter is discussed with the Navy Stock

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[1] It should be recognized that holding costs for the portion of the inventory which was not replenished is not included and that total costs therefore must be greater. To be more accurate the $5,818,400 cost would be applicable only to those items replenished, i.e., as projected by the sample, approximately 94,700 items.

Fund budget analyst, the tendency is to reduce the buy quantities to conserve Navy Stock Fund money. The implication is that, although Navy Stock Fund expenditures are reduced, they are reduced only at the expense of an overall total cost increase. The Ships Parts Control Center is currently ordering one-sixth of their economic order quantities (Lambda = 0.183) because of the limited availability of Navy Stock Fund money. The implication from the analysis is that, whereas the total annual costs for carrying the inventory should be $5,818,400, based on the cost parameters utilized, actual total costs for those items replenished exceed $15,121,900 (based on the value Lambda = 0.2 from Table 1). This would indicate that the hand-to-mouth operation used in managing Ships Parts Control Center's inventory is costing the U. S. economy $9,309,400 more than necessary.

These costs would be most difficult to verify from the appropriation structure since they would be dispersed throughout the supply system and, as noted previously, include charges that are not in the Navy appropriation structure. The estimated amount for purchases of Navy Stock Fund Material for Ships Parts Control Center, Mechanicsburg, Pa., for the fiscal year 1963, is almost $170,000,000.[1] Part of the costs, for example, included in the total cost of inventory management would be the interest charge on the average amount held. Also, it would be inappropriate to make

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[1] BuSandA, Navy Stock Fund, loc. cit., p. 70.

a comparison of the balance of the costs with appropriated amounts, especially since the value of lambda as one-sixth (.183) has been in effect for a part of the year only. But the bulk of the costs of inventory management are funded by the appropriation, Operation and Maintenance, Navy. The Bureau of Supplies and Accounts' allocation of this appropriation for the fiscal year 1963, was $297,600,000. The Navy supply system manages approximately 1,200,000 items, of which Ships Parts Control Center, Mechanicsburg controls about 160,000 or approximately 13%. It would be incorrect to consider that the amount necessary to support the ordering, holding, and issuing of material controlled by Ships Parts Control Center, Mechanicsburg, would require the annual expenditure of $36.4 million (13% of the O&M funds under the control of the Bureau of Supplies and Accounts) since there are other functions financed by this appropriation. But it is not unreasonable to believe that the cost of ordering and holding the operating level of supply of those items controlled by Ships Parts Control Center exceeds the amount indicated in the total cost analysis. It must be emphasized that in the computation Ships Parts Control Center, Mechanicsburg, in the case of storage charges and interest rate used the rates prescribed by higher authority. Their relationship to actual costs is certainly open to question. Also, in the case of ordering costs used, the definition of the ordering costs is arbitrary--it considers only those costs incurred at Ships Parts Control Center, Mechanicsburg.

The total cost average of $25 rather than a variable element of the ordering costs of the supply system was used. What the actual variable ordering cost should be, as contemplated for use in the formula, is not known or substantiated by any studies to the author's knowledge.

Navy Costs of Inventory Management

However, despite the lack of information regarding the specific costs, the magnitude of some of the cost elements can be considered from a Navy viewpoint. Many of the ordering and holding costs are merged with each other and with other costs in the present accounting structure. However, the Servicewide Supply part of the appropriation, Operation and Maintenance, Navy 1963, is approximately $297,684,000. A breakdown of the amounts budgeted is shown in Table 2.[1] Certain elements might be isolated for applicability in this case. The Navy supply system operations part of the appropriation (Management code OH in Table 2) is budgeted at $172,032,000. Inventory control point operations (Code OS in Table 2) is budgeted at a cost of $54,787,000. Whatever percentage of the total effort is devoted to purchasing, ordering, receiving, and intra-Navy shipping is properly allocable

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[1] The information in Table 2 is taken from a report, Serial 63-4 of 14 February 1963, prepared by the comptroller of the Bureau of Supplies and Accounts for the Chief of the Bureau.

TABLE 2

APPROPRIATION OPERATION AND MAINTENANCE, NAVY SERVICEWIDE SUPPLY--FY 1963, ALLOCATIONS ($000)

Mgmt Code	SH-Project	First Half	Third Quarter	Fourth Quarter	Annual Total
OH	2310-10 Operations	78,605	38,689	37,089	154,383
	20 Travel	272	119	104	495
	95 Disposal	2,386	1,225	1,089	4,700
	62 Equipment	824	92	--	916
	63 Major R & M	990	217	--	1,207
	64 Recurring M & R	5,343	2,431	2,351	10,125
	65 Minor Const & Alter	153	37	10	200
	93 Prod of L&T Products	6	--	--	6
	TOTAL - OH	88,579	42,810	40,643	172,032
OS	2315-15 ICP's-Operations	26,094	12,864	13,078	52,036
	20 Travel	420	199	264	883
	95 Disposal	15	5	--	20
	62 Equipment	261	--	--	261
	64 Recurring M & R	56	14	17	87
	66 Cataloging	750	375	375	1,500
	TOTAL - OS	27,596	13,457	13,734	54,787
OM	2350-50 Salaries	2,458	1,218	1,400	5,076
	20 Travel	122	59	49	230
	31 Equipment	5	2	3	10
	32 Supplies & Services	264	135	90	489
	95 Disposal	11	8	9	28
	TOTAL - OM	2,860	1,422	1,551	5,833
OR	2310-10 Operations	1,069	562	582	2,213
	20 Travel	22	10	5	37
	TOTAL - OR	1,091	572	587	2,250
OD	2310-10 (OI) Opers.-AIGSC	6	3	2	11
	12 Transportation	28,975	10,788	--	39,763
	20 (OI)Travel-AIGSC	19	7	12	38
	61 Misc. Services	6,763	2,017	1,910	10,690
	SUB-TOTAL	35,763	12,815	1,924	50,502
	2315-15 Commissary Stores	2,040	1,280	1,653	4,973
	15 (OW) Opers.-NSRDF	164	87	93	344
	20 (OW) Travel-NSRDF	6	3	1	10
	61 Misc. Services	3,422	1,861	1,590	6,873
	95 Disposal	26	26	28	80
	SUB-TOTAL	5,658	3,257	3,365	12,280
	TOTAL - OD	41,421	16,072	5,289	62,782
TOTAL APPROPRIATION		161,547	74,334	61,803	297,684

to the total cost of ordering. The variable elements of these costs cannot be determined without further analysis and a definition of an appropriate time-frame. Other ordering costs from Table 2 would include purchasing operations (Management code OR) budgeted at $2,250,000. Also, the percentage of transportation costs (under code OD) of $39,763,000 applicable to intra-Navy shipments would be a cost of ordering. Data to allocate some of these costs may be available from other sources. For example, workload data relative to the receipt and issue of material is contained in another report as shown in Table 3. Based on the FY 1962 data from Table 3, it appears that of the total line items handled by the Navy supply system, approximately 22 percent were receipts for stock. This is presumably a measure of the ordering volume although it would be inappropriate to apply this percentage to the total costs incurred, since many of the costs are unrelated to the ordering of stock material. From Table 3 it can also be noted that about 25% of the line items handled for Ships Parts Control Center controlled ships repair parts (H cognizance items) were receipts into stock, somewhat higher than the system average. In a report prepared for the internal consumption of the Bureau of Supplies and Accounts, it is noted for the fiscal year 1962, that while material under the control of the Ships Parts Control Center, Mechanicsburg, accounted for about 15 percent of the supply actions, Ships Parts Control Center orders accounted for almost 38 percent of the total purchase

TABLE 3

HIGHLIGHTS OF INVENTORY CONTROL OPERATIONS AT SUPPLY DISTRIBUTION ACTIVITIES[a]

	FY 1962		FY 1963	+ or - Percent Change over 4th Qtr
	Total	4th Qtr	1st Qtr	
System Summary (All Cognizance)				
1. Demand Requests Processed	28,411,172	6,942,962	6,104,091	- 12.1
2. Material Availability				
a. Gross (%)	83.6	82.6	83.2	+ 0.6
b. Net (%)	89.8	89.1	89.2	+ 0.1
3. Line Items Issued	25,662,908	6,251,910	5,407,774	- 13.5
4. Receipts for Stock	7,179,766	1,900,770	1,376,553	- 27.6
Ships Assemblies and Repair Parts (H)				
1. Demand Requests Processed	2,581,180	618,036	491,821	- 20.4
2. Material Availability				
a. Gross (%)	71.5	72.2	71.1	- 1.1
b. Net (%)	82.2	82.1	80.3	- 1.8
3. Line Items Issued	1,992,483	489,773	395,085	- 19.3
4. Receipts for Stock	750,991	188,001	148,719	- 20.9
Submarine and Nuclear Equipment and Repair Parts (P)				
1. Demand Requests Processed	235,329	67,525	57,793	- 14.4
2. Material Availability				
a. Gross (%)	64.4	62.8	61.0	- 1.8
b. Net (%)	80.6	81.1	73.1	- 8.0
3. Line Items Issued	172,607	49,255	41,984	- 14.8
4. Receipts for Stock	87,833	27,672	24,549	- 11.3

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[a] Information in this table is taken from Bureau of Supplies and Accounts publication *Inventory Control Operations at Supply Distribution Activities*, NavSandA Publication 295, First Quarter Fiscal Year 1963 (Washington: BuSandA, FY 1963), p. 3.

actions of the supply system.[1] This would indicate that inventory decisions for the ship's parts segment of the supply system are responsible for a higher percentage of the total ordering costs than other inventory decisions. Presumably, these decisions should have been made in the light of this information. The variable element of the ordering costs incurred is not known.

In connection with both ordering and holding costs, certain other statistical data are available in the performance progress report cited previously[2] as shown in Table 4. The difficulty in allocating these costs, which were collected by work measurement function, to either ordering or holding categories can be seen in the possible allocations attempted in column 4 of Table 4. The further problem of determining the variable elements involved is even more difficult.

Other data are available in the budget report submitted by the Bureau of Supplies and Accounts for the Navy Stock Fund. For example, it appears some validity can be ascribed to the 5-33 percent obsolescence risk rates used by the Ships Parts Control Center, Mechanicsburg, in their cost analysis. For the fiscal year 1963, the budget indicates approximately $88,261,000 will be received by the Navy Stock Fund from appropriations of consumers as surcharges. In addition to this, approximately $80,146,000

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[1] Bureau of Supplies and Accounts, Performance Progress Report, (Washington: BuSandA, Fiscal Year 1962), pp. 12-13.

[2] *Ibid.*, pp. 3-5.

TABLE 4

PARTIAL LISTING OF OBLIGATIONS BY WORK MEASUREMENT FUNCTION FOR THE FISCAL YEAR 1962[a]
(in thousands)

Function	Supply Operations	Supply Management	Possible Allocation
Storage Control	$9,032	$-	Holding-Storage
Storage Custody	10,294		Holding-Storage
Disposal Operations	4,530	46	Obsolescence
Storage Operations	9,620		Holding-Storage
Public Works M&O	36,281		Various %Storage %Other
Stock Mgt (Control)	23,065	15,134	Various %Orderin %Other
Admin. Operations	19,380	10,969	Various
Traffic, Rec., Ship.	13,823		Various %Orderin %Other
Purchase	2,250	4,404	Ordering
Other Functions	b	b	Various
Total Obligations	$218,879	$78,981	

[a] The information contained in columns 1 through 3 is taken from a Bureau of Supplies and Accounts report, Performance Progress Report, (Washington: BuSandA, Fiscal Year 1962), pp. 3-5. This report has been discontinued.

[b] There are several other functions involved; however, since most of the data are not pertinent, they are not reproduced here.

will be written off as stock losses.[1] While these costs are shown as stock losses and other inventory adjustments, supporting schedules indicate most of these changes are transfers to disposal. For ships parts alone the amount which was transferred to disposal during the fiscal year 1963 was budgeted to be $44,500,000.[2]

With respect to interest costs, total Navy Stock Fund inventories of peacetime operating stock are estimated at about $620 million.[3] The interest cost of holding this amount of material in storage at the Department of Defense directed rate of 4 percent would be a significant $24.8 million. If a higher rate of interest were considered appropriate on the basis of alternative uses, the cost of interest would be proportionately higher. Since any reduction in the inventory releases funds for other uses, it is basically a variable element of cost and could be reduced proportionately with the reduction of inventories. The extent of any savings derived by reduction of this cost will, of course, not appear in any Navy appropriation and is, therefore, not subject to verification.

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[1] Bureau of Supplies and Accounts, Navy Stock Fund, Fiscal Year 1963 Reapportionment, Fiscal Year 1964 Budget Estimates, (Washington: BuSandA, 1 October 1962), p. 10.

[2] Ibid., p. 70.

[3] Ibid., p. 10.

Summarizing, the magnitude of the costs involved are:

Cost Element	Amount (thousands)
Servicewide Supply (O&M)	$297,684
Navy Stock Fund (Disposal)	80,146
Other Appropriations (NSF Surcharges)	88,261
Interest (4%)	24,800
Total costs indicated	$490,891

This is not to say other costs are not involved. Military Pay, Navy, Military Construction, Navy, as well as other appropriations, contribute a portion of the costs allocable to inventory management decisions, but the method of allocation is so nebulous as to almost defy analysis. The above is presented only to give the reader some perspective as to the magnitude of the costs involved.

The cost data above cannot be related to the total cost analysis of Ships Parts Control Center, Mechanicsburg. But inventory decisions in the long run should reflect the total costs involved. Quantitative analysis will help, especially if the costs are segregated as in the case of the method currently in use at Ships Parts Control Center, Mechanicsburg. The value in using lambda in the computation of requirements is that it points up a potential area for the reduction of costs and for increasing efficiency in the management of inventories. The

implication of the analysis is not necessarily the conclusion. The conclusion is that prudent managers should be so motivated by such a possibility that no effort is spared in determining the cost parameters which are necessary to verify or refute the implication. Industry has used economic lot theory for many years. Many refinements have been made. The economic order quantity formulae has been generally accepted by management in industry as the most efficient method for those items where it is applicable. With increasing costs and narrowing profit margins, industry has been hard pressed to find the most economical way of managing inventories. Economit lot production is a way of life in our mass-production-oriented economy. Industry has found it absolutely mandatory to determine cost parameters. Profitability of products can be determined only after all costs are allocated. Cost accounting techniques have been developed so that a reasonably accurate estimate of fixed semi-variable and variable cost-elements are determined. These are the very same cost parameters needed to confirm or refute the implication Navy inventories are not managed most economically.

The point is this; currently, we do not know.

CHAPTER IV

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

It is implied by the data presented in this thesis that we may not be managing our inventories economically. It is concluded, based on the research necessary for this thesis, that we simply do not know. Further, we cannot be sure until we know what are our inventory management costs. These costs are so widely dispersed throughout the Navy appropriation structure and elsewhere, that they are difficult to determine.

A second conclusion is that studies made to date to determine the cost parameters of Navy inventory management are, at best, inadequate. Such data as have been generated, have been summarily rejected as a basis for justifying budget requirements by both the Department of Defense and Bureau of the Budget budget analysts.

A third conclusion is the fact that economic order quantity formulae have been used for decades by industry with increasing effectiveness for both economic lot production and inventory management. It is now generally accepted in industry as

the most efficient method of inventory management. To do this, it has been necessary for industry to determine its inventory management cost parameters; in fact, through cost accounting techniques, reasonable estimates have been determined with respect to their fixed, semi-variable and variable elements.

Finally, we in the Navy can also make these same cost parameter determinations; these determinations would be helpful for budget and management purposes, but a longer time frame of reference must be used for long-range efficiency.

A note of caution is inserted here; if economic order quantity formulae are utilized, the conditions precedent to their use must exist. They can reduce costs. They will not solve inventory management problems except with respect to random variation. Misapplication of the formulae remains as a constant danger.

Recommendations

It is recommended that a major effort be expended in the direction of determining cost parameters applicable to the management of those segments of the Navy Department's inventories susceptible to replenishment by economic order quantity formulae.

It is recommended that an agreement be reached between Navy representatives and the Department of Defense and Bureau of the Budget analysts as to the time-frame of reference which should

be used for the determination of the variable elements of the costs involved. As a corollary, it is recommended the time-frame be extended beyond the budget year on the premise that in the long run all costs are variable. If when costs are reviewed there are considered only these inputs which are variable on an annual basis, many costs would not ever be included. As a compromise, it is suggested all costs over a five-year period be considered as variable (on a progressive basis) to coincide with the current policy of planning as practiced by the Department of Defense for budget analyses.

Finally, it is recommended, once acceptable ground rules for cost parameter analysis have been established, and cost parameters determined, that inventory managers utilize the economic order quantity formulae to the extent applicable for replenishment purposes for budget justification and for management decisions.

APPENDIX I

Samples Used for Simulation[1]

A. The Need for Samples.

Using the complete Perpetual Inventory Record (PIR), approximately 181,000 items, in a simulator is not economically feasible. To run the complete PIR through Simulation would require approximately 22 hours of machine time, while a 10% sample of the PIR would require approximately 2 hours, and a 1% sample 12 minutes. Hence economy demands that sampling be used.

B. Sampling Scheme.

There are numerous ways to select a sample: select every 10th item on the stock list, or every item ending in 67 or 97. Any scheme is valid if it produces a sample which is representative of the universe.

Thus the essential quality of a sample is its representativeness, and with our heterogeneous stock list this presents problems, particularly if the simulator produces output

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[1] Advanced Logistic Research and Development Branch, Ships Parts Control Center, Mechanicsburg, Pa., A Single Warehouse System Simulator, Simulator Beta, (Ships Parts Control Center, Mechanicsburg, Pa.: 12 December 1961).

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1. [illegible]

[illegible]

2. [illegible]

[illegible]

[illegible]

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[1] [illegible]

heretofore unavailable, and therefore not subject to comparison with known characteristics of the universe.

Representativeness of a sample may be determined by the ratios of the sample to the universe in the number of F items, S items, distribution of $\overline{Q}$, unit price, etc. But how can it be determined that a sample is representative of the stock list if it used in a simulator to produce output for which no criteria for comparison exists: output such as average risk and $EO\overline{Q}$, number of buys and dollars required for stock replenishment.

If this is the situation then the determination of representativeness must be made indirectly rather than through a direct ratio comparison. Several samples are selected randomly and run through the simulator. Then an analysis is made of the simulator output to see if all the samples maintain a reasonable consistency in all results. This being true, the assumption is made that any or all the samples are representative of the stock list.

To perform this analysis four 10% samples were selected in the following manner:

Sample

1. AA 1st and every subsequent 10th item.
2. BB 3rd and every subsequent 10th item.
3. CC 5th and every subsequent 10th item.
4. DD 8th and every subsequent 10th item.

Also, four 1% samples were selected:

Sample

1. A 1st and every subsequent 100th item.
2. B 25th and every subsequent 100th item.
3. C 50th and every subsequent 100th item.
4. D 75th and every subsequent 100th item.

These eight samples were selected from the PIR as of week 02, the first review of FY 1962 after the PIR update and before the Supply Demand Review of week 02.

C. Sample Determination.

The four 10% samples were analyzed for consistency of results, and proved to be satisfactory, having an average overall error in results of 4.8%.

The average error was obtained in the following manner:

The average risk of each sample is

Sample	Average Risk	Error (Actual - Mean)
AA	17.684	.009
BB	17.738	.063
CC	17.728	.053
DD	17.551	.124
	70.701	.249

$$\text{Mean} = \frac{70.701}{4} = 17.675$$

$$\text{Mean Average Deviation} = \frac{.249}{4} = .06225$$

To convert the mean absolute deviation into an expression which indicates the average percentage error, divide the mean average deviation (MADO by the mean ($\overline{X}$):

$$\frac{.05225}{17.675} = 0.35\%$$

This average percentage error is equivalent to the MAD expressed as a percent of the mean.

The type of analysis was performed on several facets of simulator output, resulting in the following average percentage errors between sample results:

Output	Percentage Error
Average System Risk	.35%
Dollar Forecast	7.17%
Number of Buys Forecast	2.39%
Number $\overline{Q}$'s (Quarterly Mean Average) = 0	.96%
Average Economic Order Quantity	4.08%
Number $\overline{Q}$'s 1.5	7.53%
Number $\overline{Q}$'s 1.5	6.90%
Total $\overline{Q}$	8.94%
	38.32%

Then an average was taken of the percentage errors, which is $\frac{38.32}{8}$ or 4.8%. This means that on the average the MAD was approximately 5% of the mean, which is believed to be a reasonable error over samples taken from such a heterogeneous universe as the Ships Parts Control Center PIR.

The 1% samples produced output of such wide variance that three of the four samples had to be discarded. Only Sample A gave results which were reasonably close to the 10% samples.

Finally Sample A, the only usable 1% sample, and Sample AA were retained for simulation.

Sample AA was retained because, of the four 10% samples, it most closely approximated the results of Sample A.

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